Prospects for Discovery of DM Annihilation to Primary Neutrinos with IceCube

Bradley Knockel
University of New Mexico

Working with...
Rouzbeh Allahverdi (UNM), Alexander Friedland (LANL),
Katherine Richardson (UNM)

INFO 13
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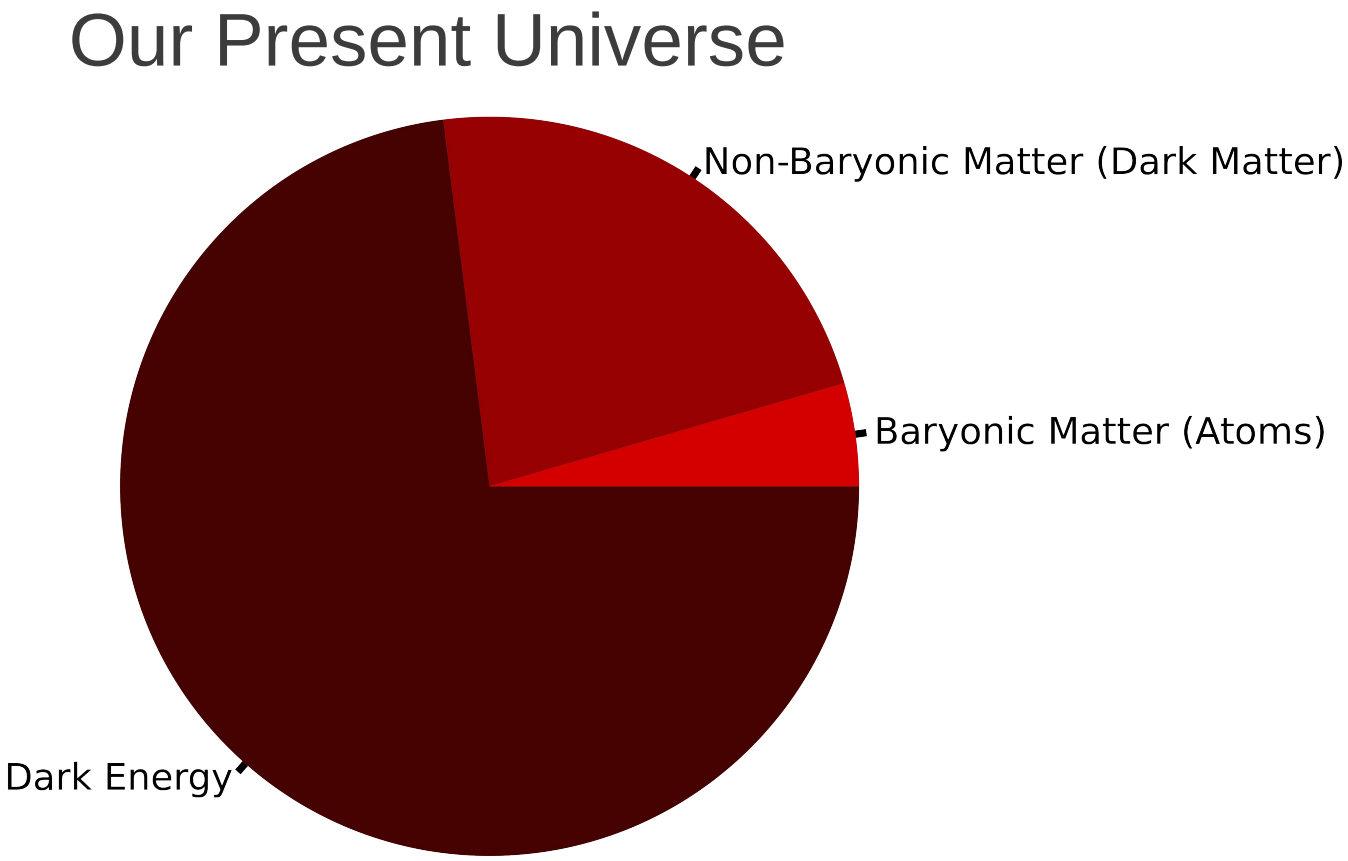
Outline

(1) Introduction

(2) Methods and Results

(3) Conclusions

What's the matter?



$$\Omega_0 = 0.683 + 0.268 + 0.049 = 1$$

The WIMP Explanation

- WIMPs (Weakly Interacting Massive Particles) are currently the best explanation for the composition of dark matter
- Particles are most likely weakly interacting. Not too strong, but we assume stronger than gravity
- Particles are massive (that is, not massless) to explain observed structure formation

WIMP Relic Density via Thermal Freeze-Out

$$\Gamma_{\rm ann} \sim H$$

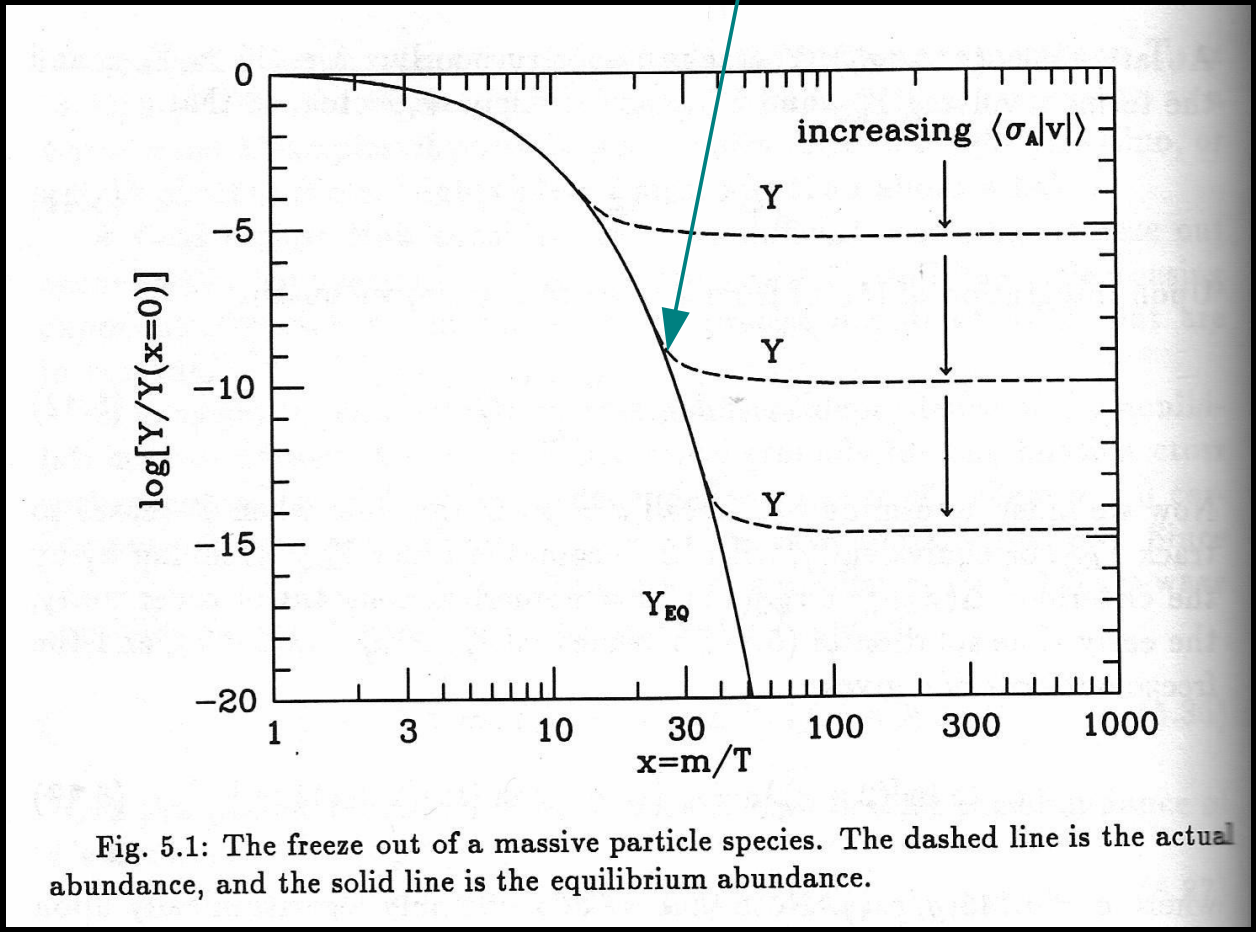
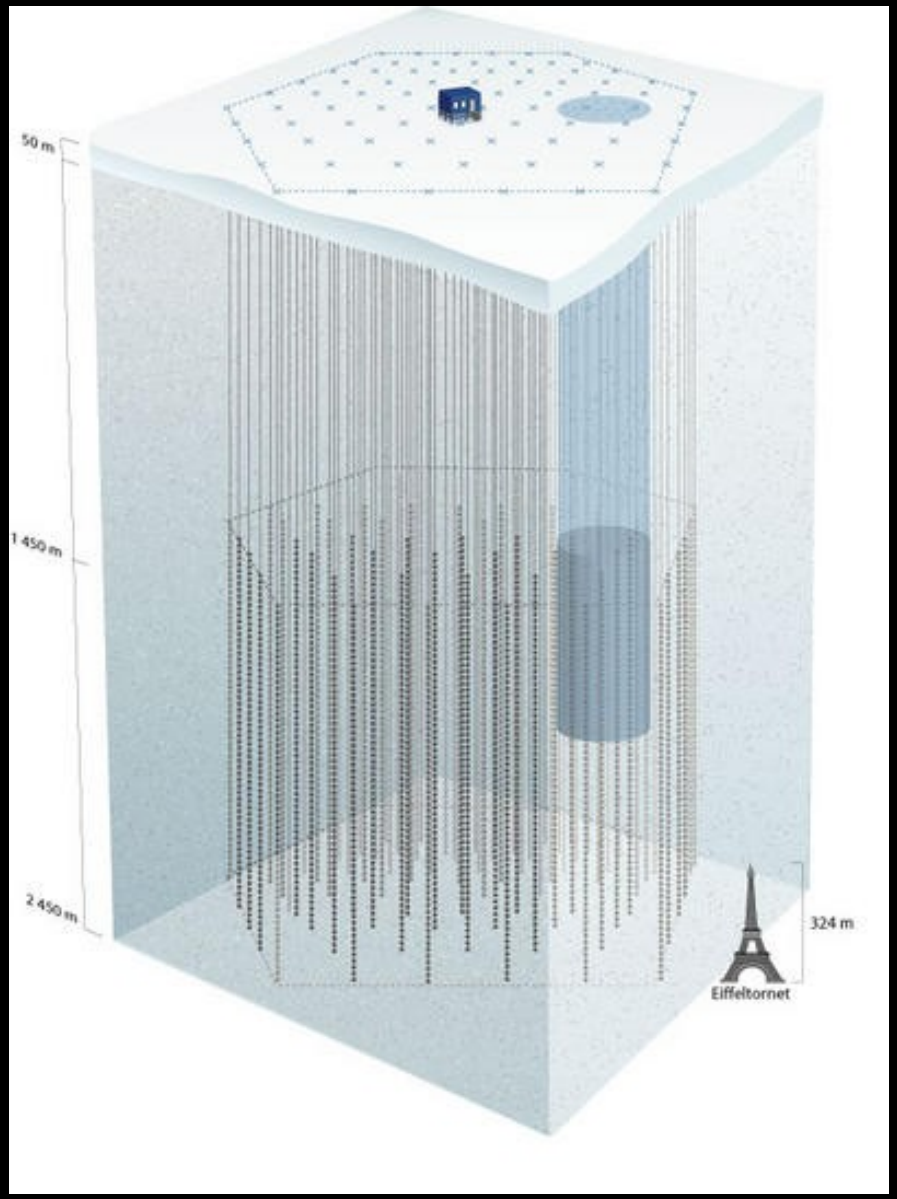


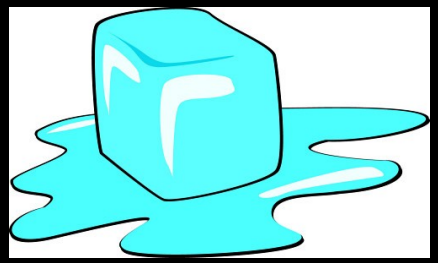
Fig. 5.1: The freeze out of a massive particle species. The dashed line is the actual abundance, and the solid line is the equilibrium abundance.

$$\langle \sigma_{\rm ann} v \rangle = 3 \times 10^{-26} \frac{\rm cm^3}{\rm s}$$

IceCube

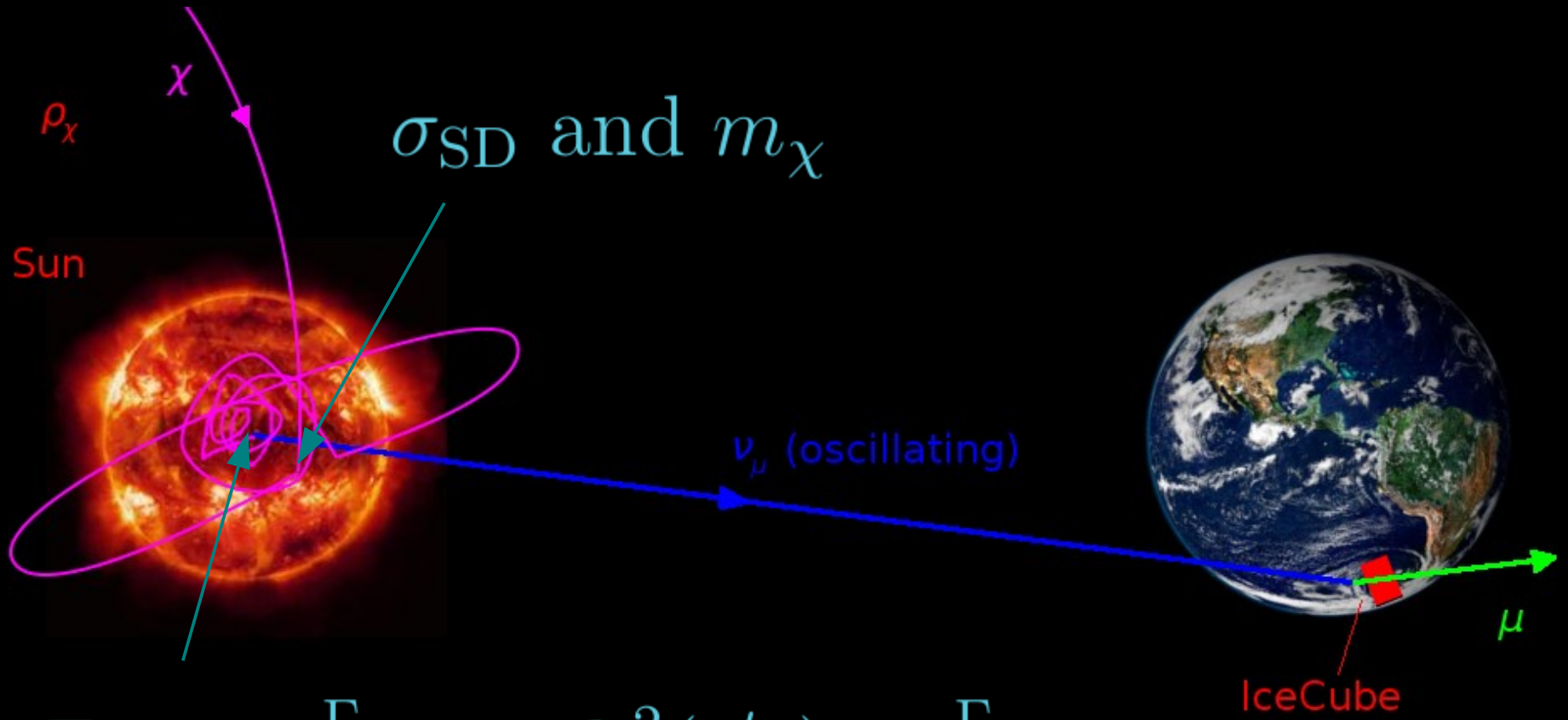


ice cube



Ice Cube

Indirect Detection via the Sun



$$\Gamma_{\mathrm{ann}} = \frac{\Gamma_{\mathrm{cap}}}{2} \tanh^2\left(\frac{t}{\tau_{\mathrm{eq}}}\right) \approx \frac{\Gamma_{\mathrm{cap}}}{2}$$

and B_i

Why Prompt Neutrinos

- The LHC has constrained the MSSM, so the neutralino may not be the WIMP
- Our analysis is model independent, and we are not biased towards the neutralino
- Many models have enhanced prompt neutrinos
- For example, if the WIMP has lepton number, it can annihilate to $\nu\nu$

Enhanced prompt neutrinos
Lindner, Merle, and Niro, Phys. Rev. D 82, 123529 (2010).

Annihilation Channel Examples

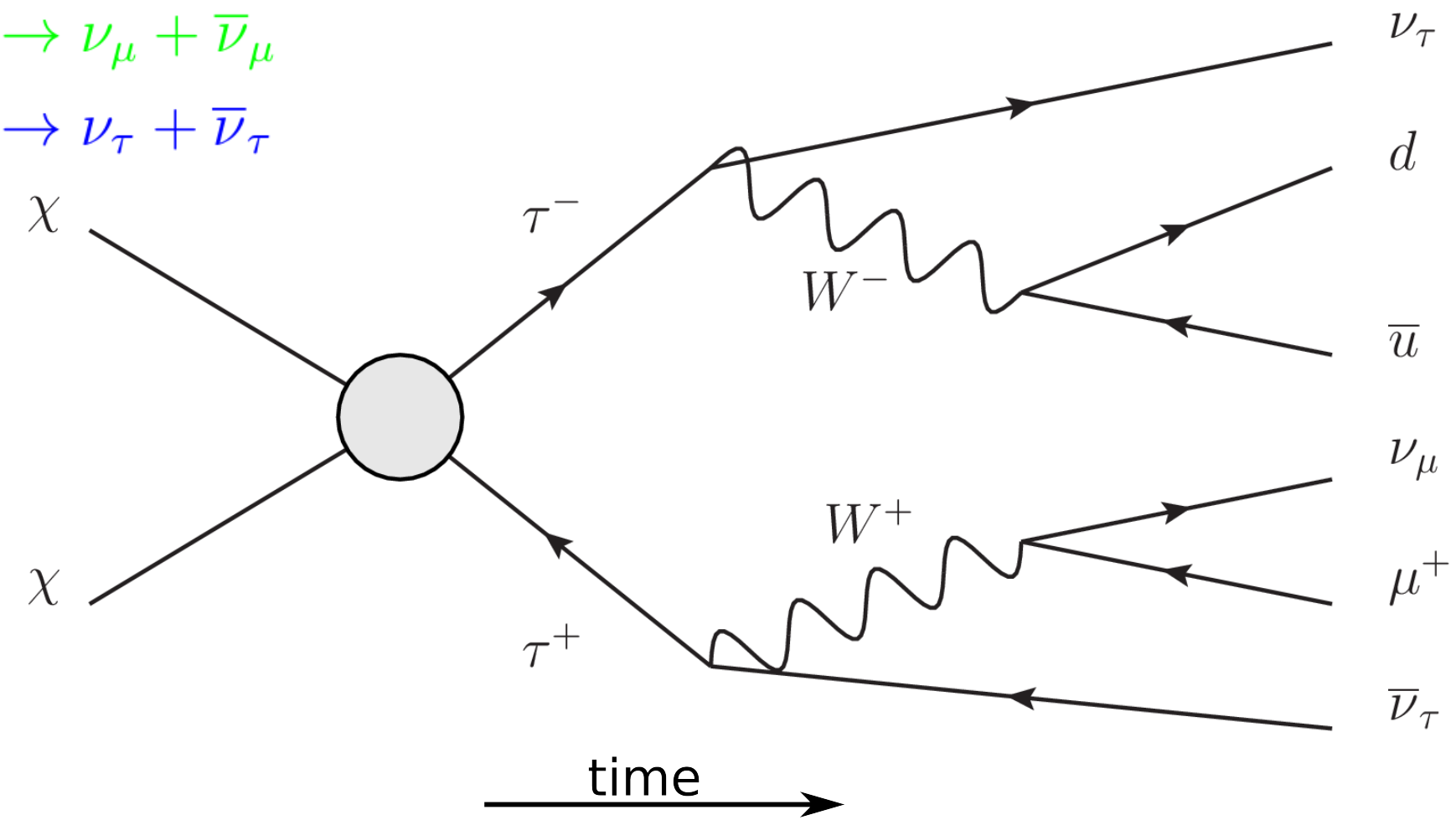
$\chi + \chi \rightarrow \tau^- + \tau^+$

$\chi + \chi \rightarrow W^+ + W^-$

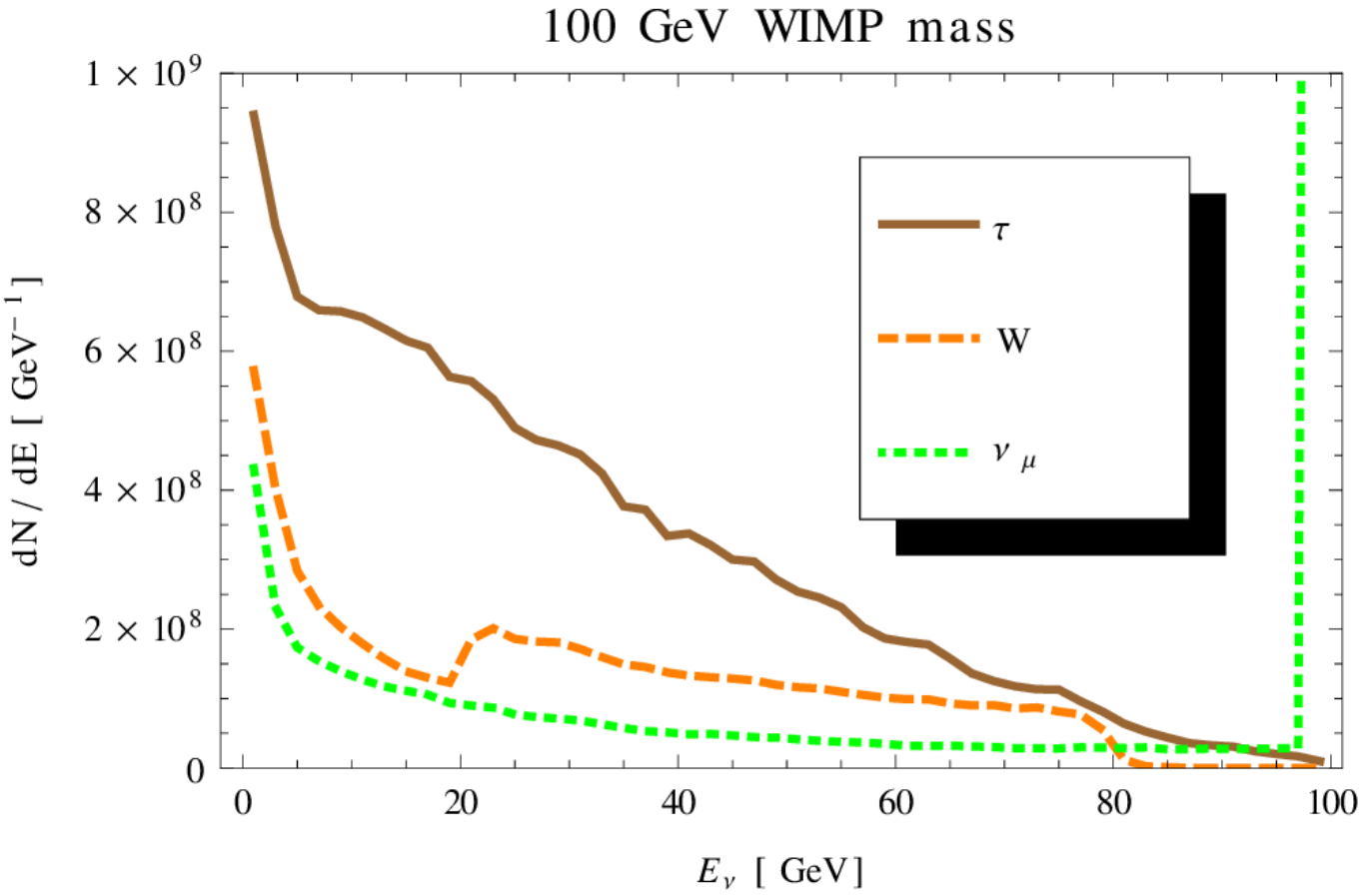
$\chi + \chi \rightarrow \nu_e + \overline{\nu}_e$

$\chi + \chi \rightarrow \nu_\mu + \overline{\nu}_\mu$

$\chi + \chi \rightarrow \nu_\tau + \overline{\nu}_\tau$



Muon Neutrinos Reaching Detector



There are corresponding angular distributions as well.

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Our Analysis

(1) Acquire simulated data for signal and background at IceCube using DarkSUSY. We acquire “contained” and “through-going” muons for a low-energy and high-energy analysis, respectively.

(2) Model IceCube’s detection of the muon tracks using published effective detector volumes and areas and by smearing the angular and energy distributions by 1° and 40 GeV respectively

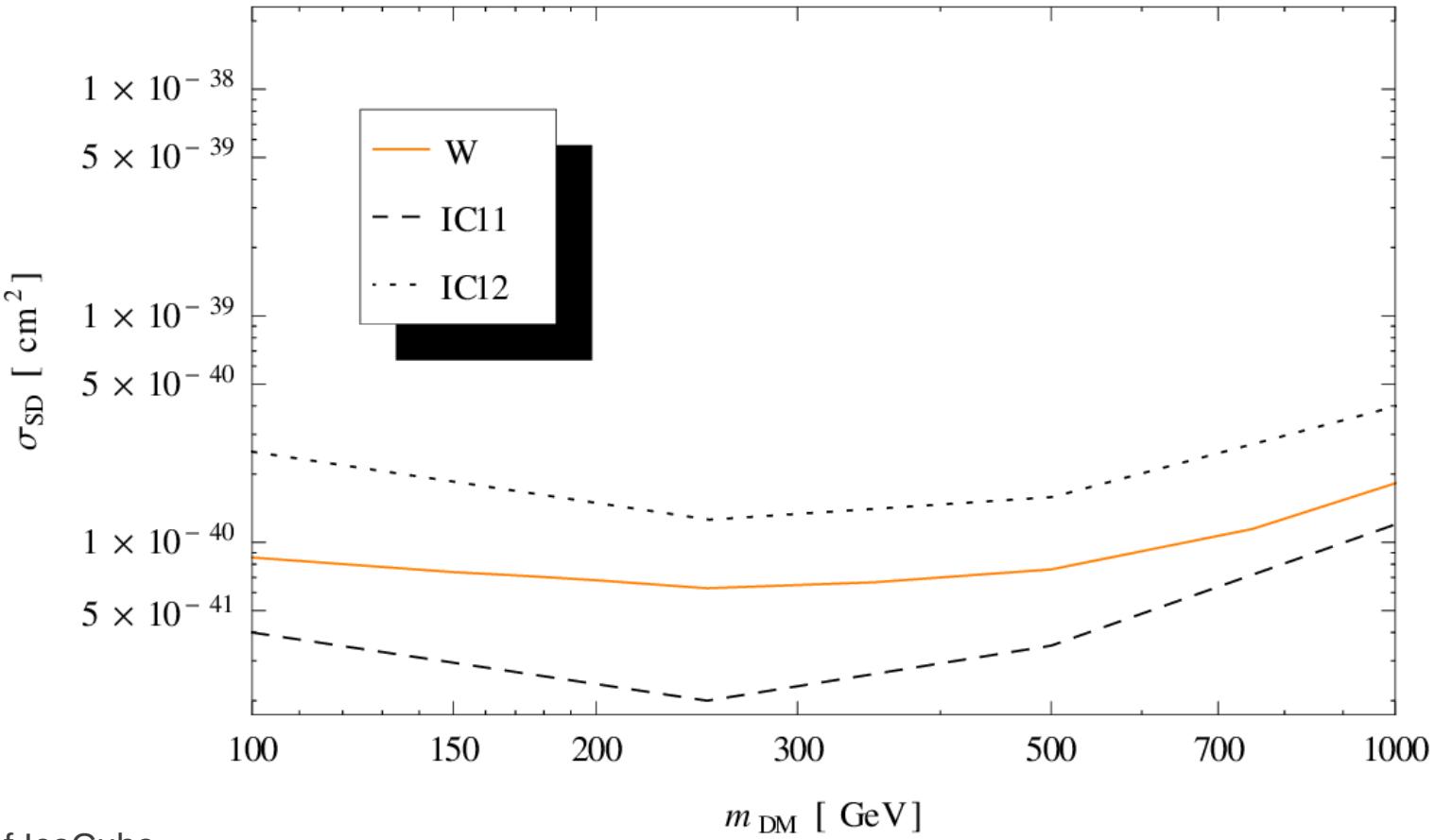
(3) Optimize the analysis for dark matter discovery at 90% confidence using a χ^2 analysis

$$\frac{S}{\sqrt{S+1.2B}} = 1.64$$

(4) Distinguish between different annihilation channels assuming a discovery and an independent measurement of mass

$$\sigma = \frac{|S_c - S_t|}{\sqrt{S_c + 1.2B_c}}$$

Benchmarking Using the *W* Channel



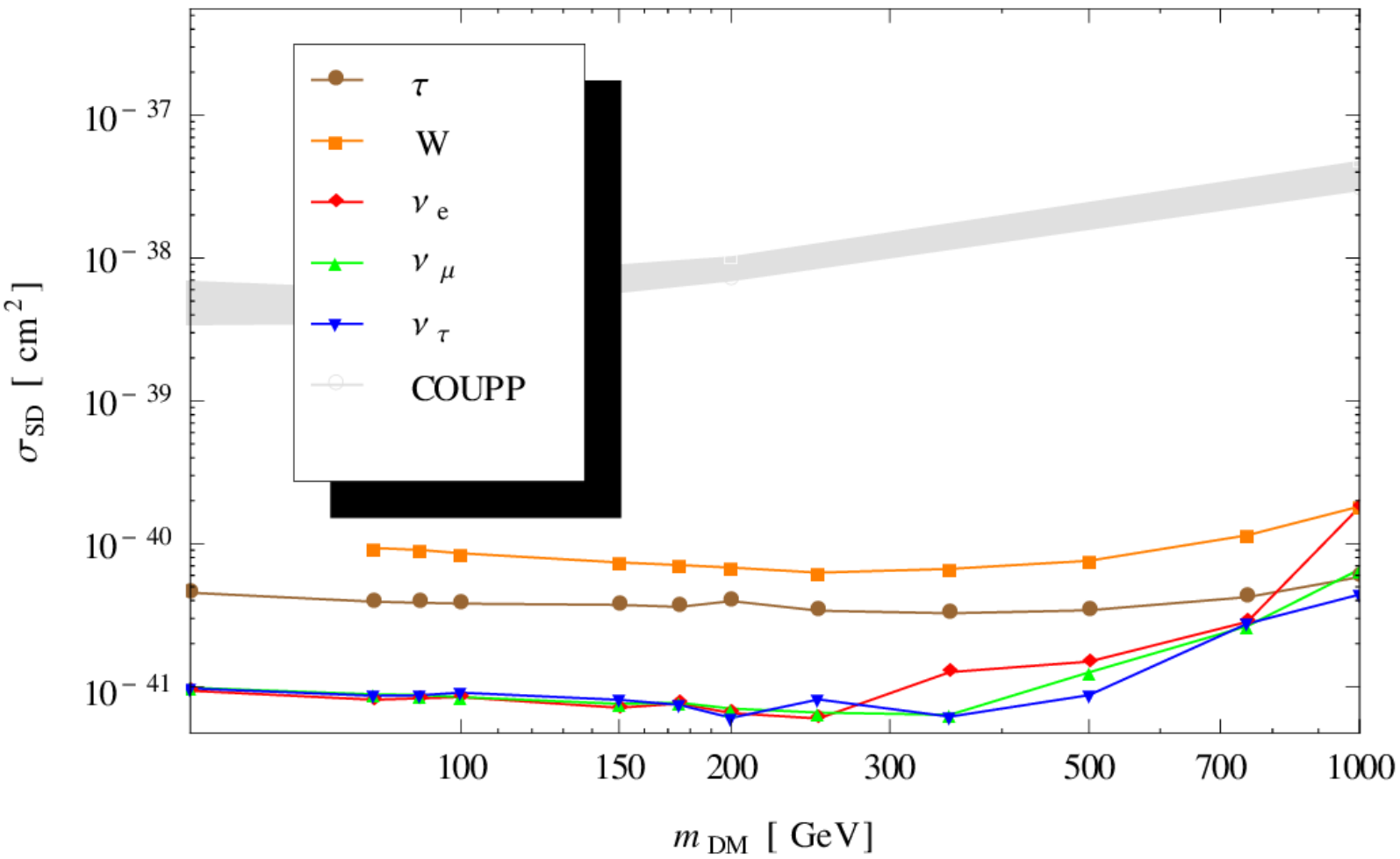
Effective Volume/Area of IceCube
Astropart. Phys. 35, 615 (2012).

IceCube 2011
Phys. Rev. D 85, 042002 (2012).

IceCube 2012
Physical Review Letters 110, 131302 (2013).

IceCube can be modeled simply.

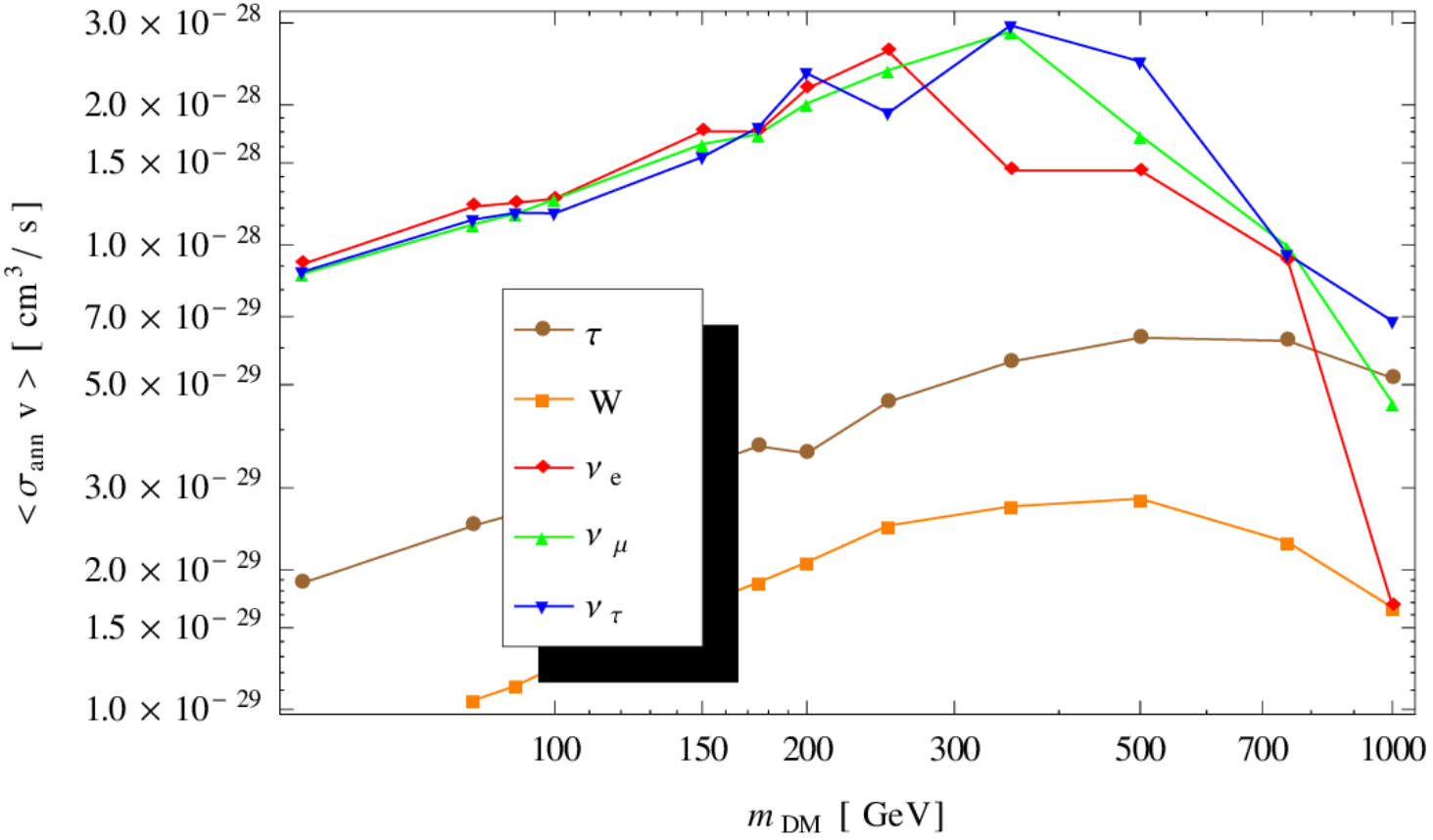
Sensitivity Plot for All Channels



COUPP
Phys. Rev. D 86, 052001 (2012).

Factor of ~8 between *ν* and *W*
Allahverdi and Richardson, Phys. Rev. D 85, 113012 (2012).

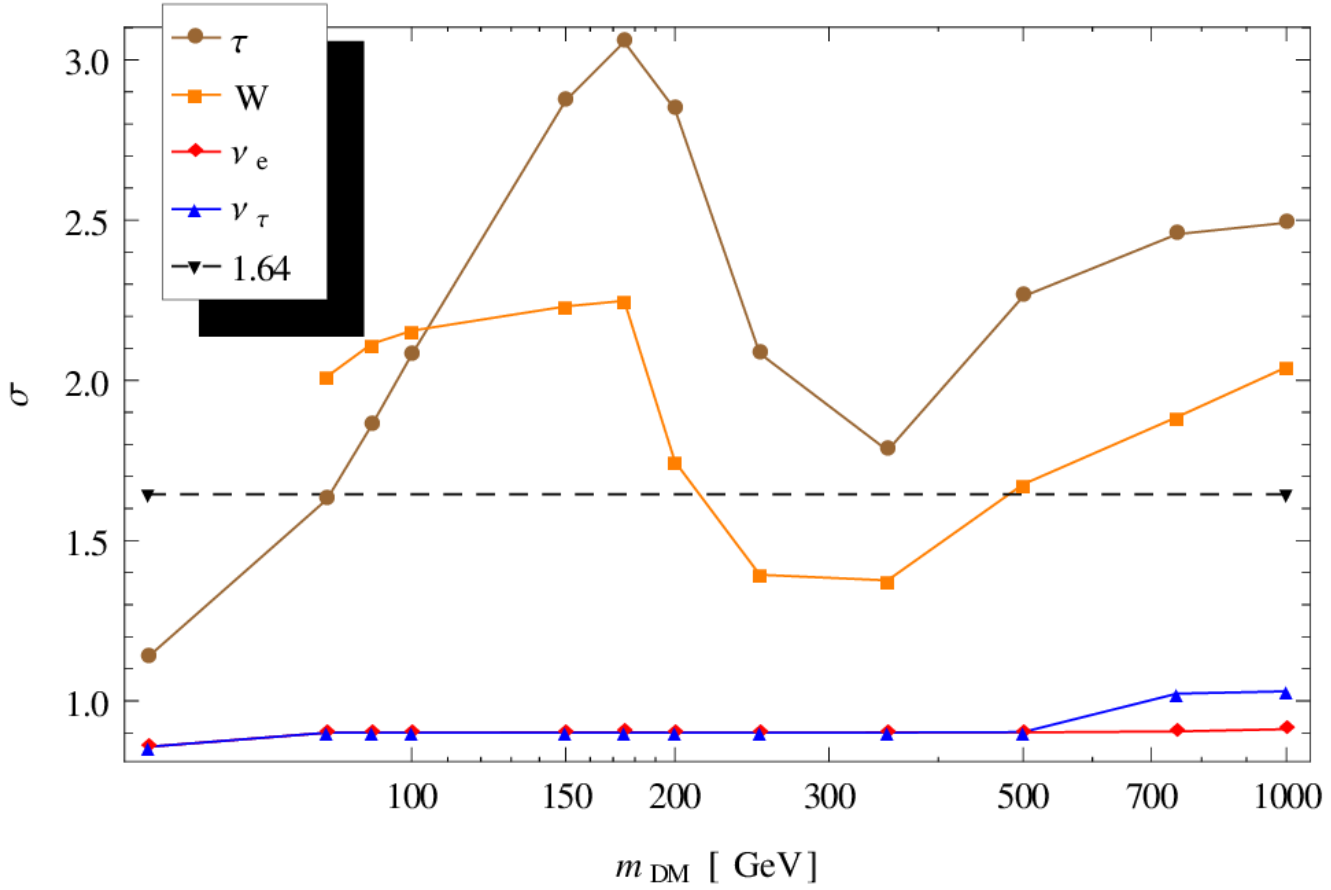
Corresponding $<\sigma_{ann}\ v>$ Required for Equilibrium in Sun



Sun might be the only way the detect prompt neutrinos.

Compare to galactic prompt-neutrino bounds of ~10^{-23}
IceCube (2011), e-Print: arXiv:1111.2738 [astro-ph.HE].

Distinguishing Channels (asking if ν_μ fits the data)



Highly sensitive to the energy smearing that we choose to model IceCube

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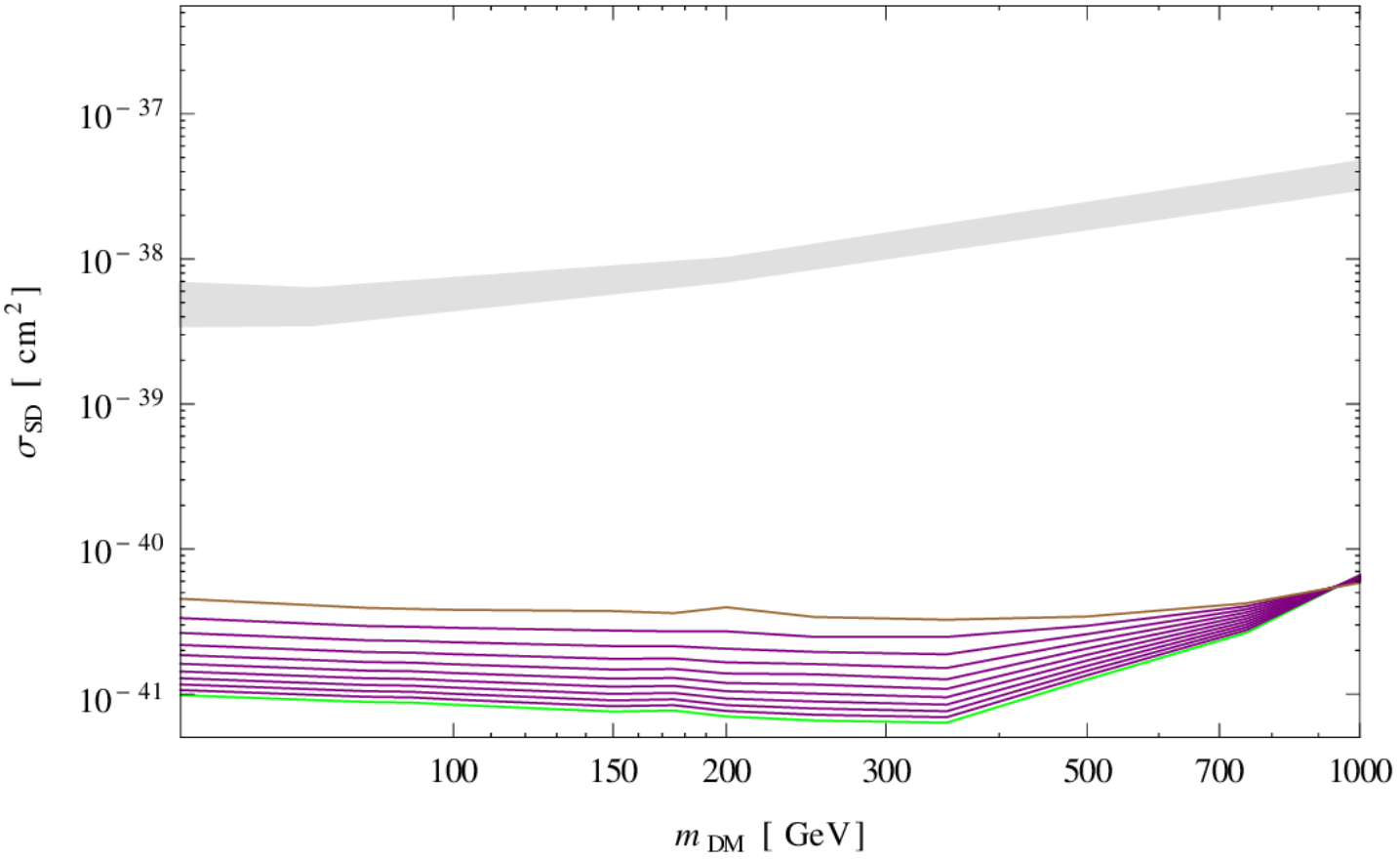
Conclusions

- We should consider prompt neutrinos
- Although the solar community ignores prompt neutrinos, indirect detection via the Sun may be the only way to detect them
- IceCube is sensitive to prompt neutrinos for DM mass < 1 TeV
- Prompt neutrinos can be distinguished from other annihilation channels

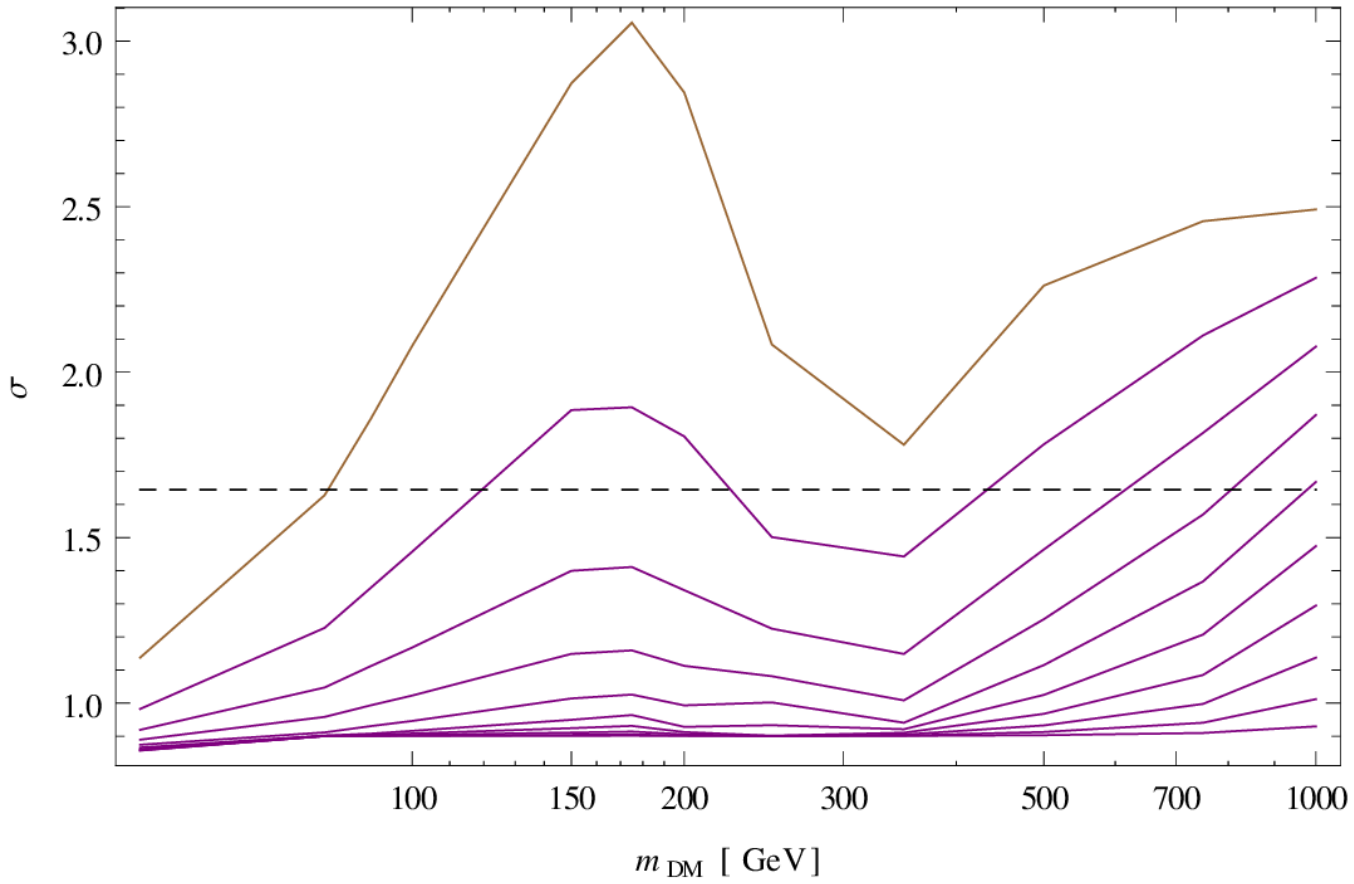
Paper on arXiv soon!

Additional Slides

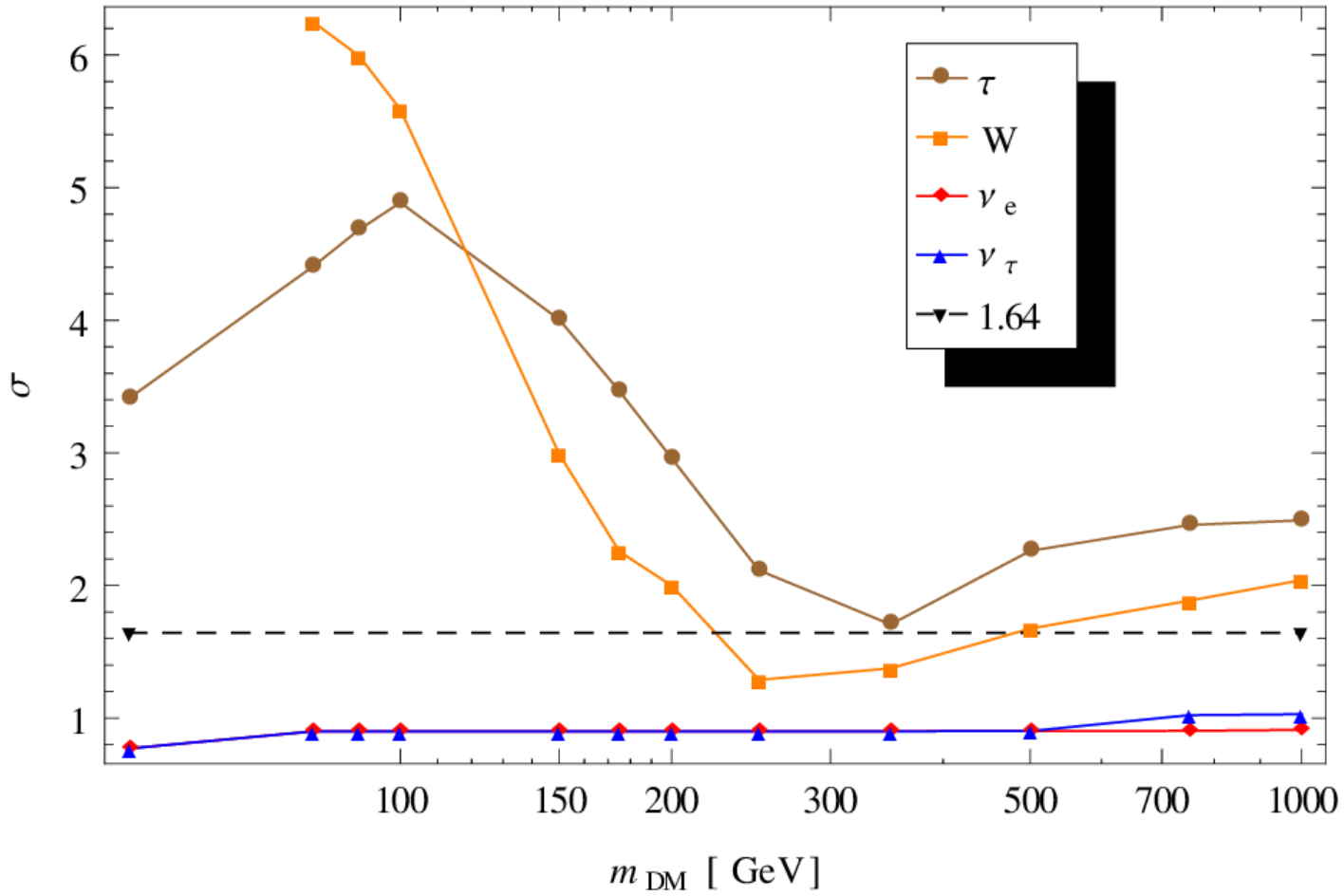
Sensitivity (τ and ν_μ mixtures)



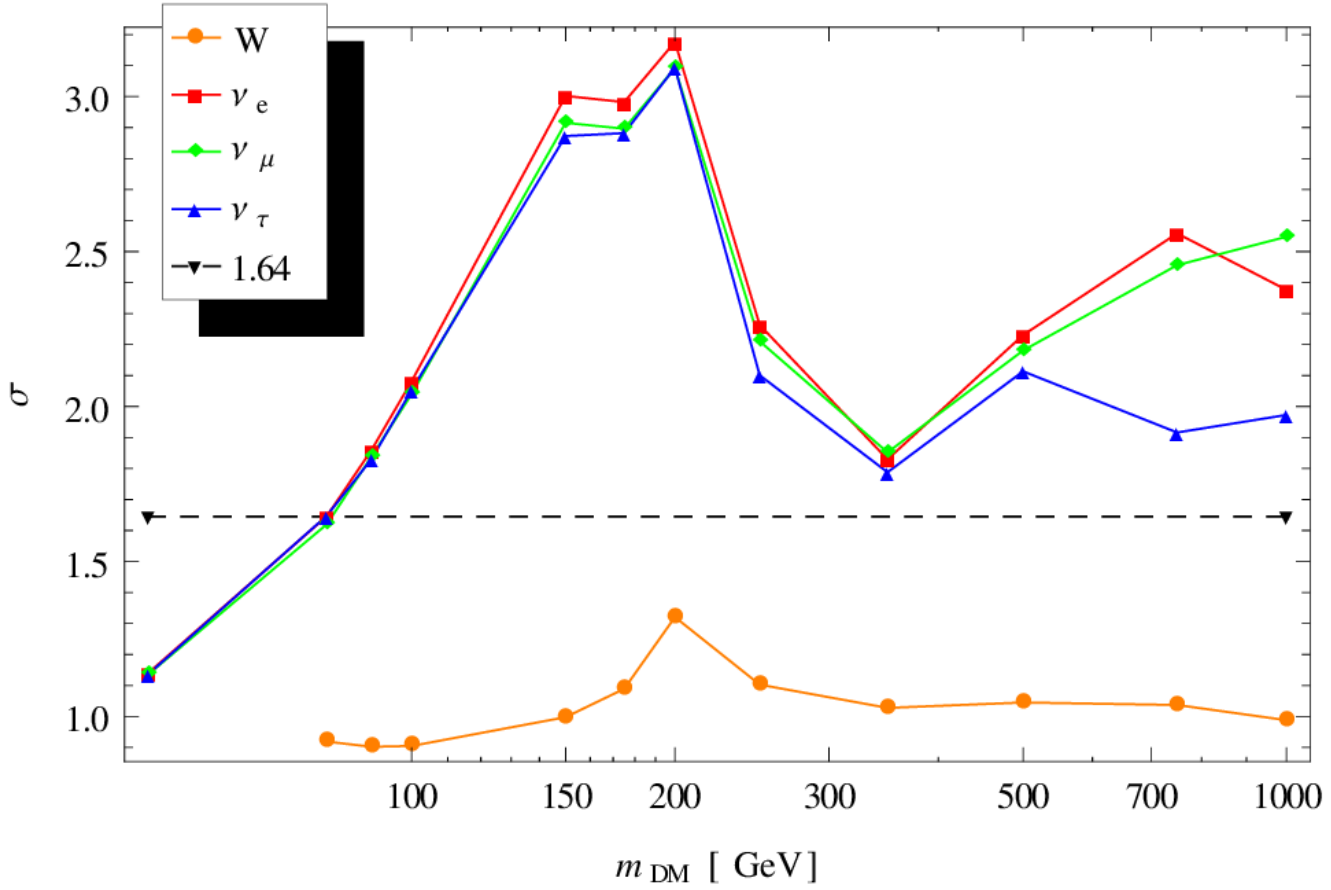
mixtures of τ and ν_μ



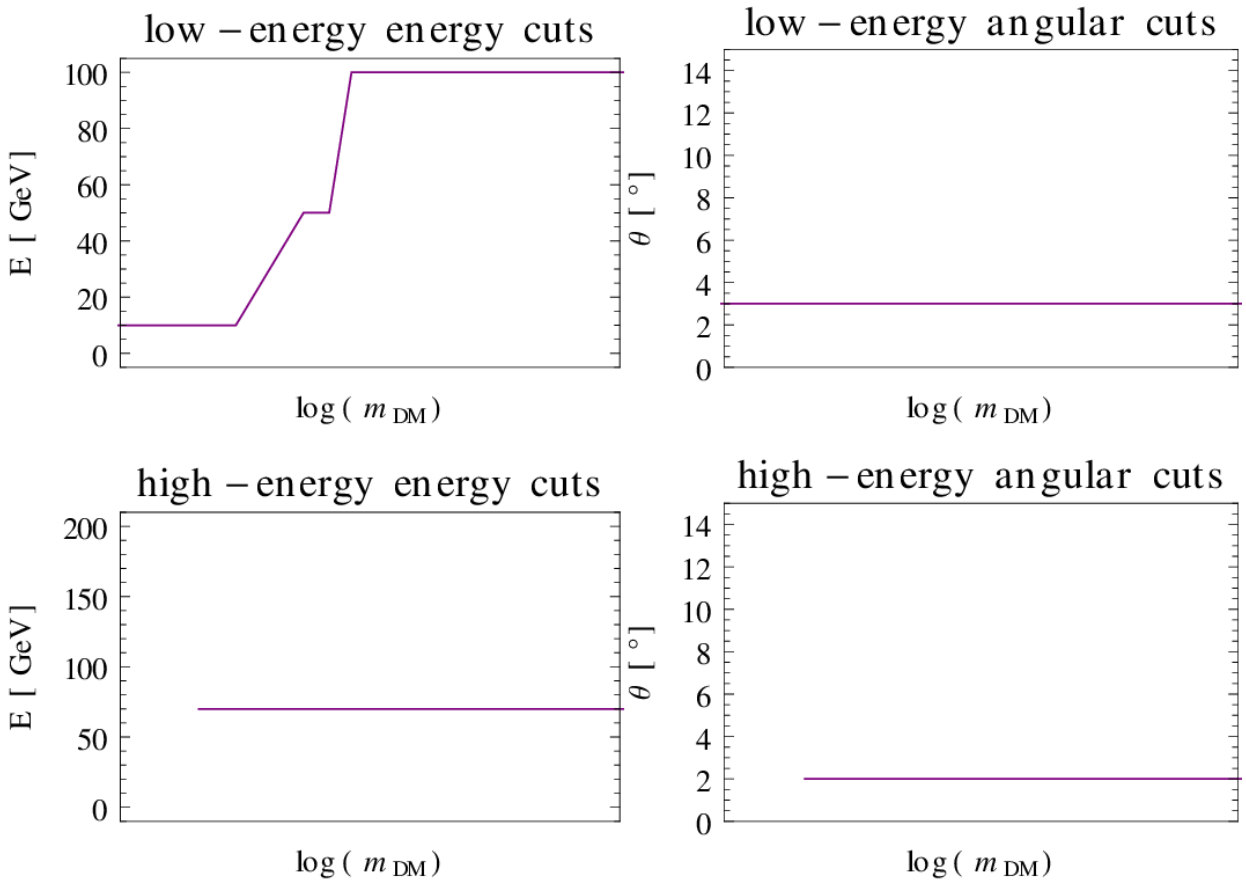
Distinguishing using 10 GeV smearing instead of 40 GeV (for low-energy)



τ as target



Discovery Cuts



First energy bin begins ABOVE energy cut, and angle is integrated up to the angular cut.

Distinguishing Angular Cuts